Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Proposed Rules Permitting Antenna	)	MM Docket No. 93-177
Modeling to Verify AM Directional	)	
Antenna Performance	)	

To the Commission:

I. COMMENTS OF J.L. SMITH, PE

J.L. Smith, PE respectfully submits these comments in the above captioned proceeding as invited by Public Notice DA 07-2143, released May 23, 2007, concerning the recommendations and draft rules offered by the AM Directional Antenna Performance Verification Coalition ("Coalition") in their letter dated May 4, 2007. The comments submitted herewith support the notion of rule changes to permit antenna modeling as verification of AM directional antenna performance. In addition, these comments endorse the Coalition's proposed draft revisions to the rules as modified by these comments, to wit:

(a) delete the requirement that the calculated self impedance of the modeled array elements match measured self impedances and replace with a requirement to confirm the validity of the moment method analysis by showing a favorable comparison of calculated field ratios and target field ratios;

(b) Disallow the opportunity to conduct the analysis using arbitrary tower heights and replace with a defined tower model;

(c) Miscellaneous changes in procedure and method

II. QUALIFICATIONS

J.L. Smith, PE is registered as a professional engineer in the states of Mississippi (#7978), Louisiana (#11041Ret) and Texas (#19315Ret). He began his broadcast career at radio station KTRH in 1946. In 1956 he joined Collins Radio Company where he held the usual positions in research and development culminating in Department Head, Research and Development. He served as Manager, Broadcast Systems Engineering at Collins Radio Company in the 1960's during which time he directed the design and development of a complete catalog of broadcast equipment, including AM directional antenna networks.

Mr. Smith is now retired and devotes the majority of his time to analytical research pertaining to AM directional antennas, particularly the use of NEC2 and NEC4 in broadcast applications. For the past 15 years, results of his work in this area have been reported in papers published in the technical journals including the IEEE Transactions on Broadcasting.

There being no commercial involvement, Mr. Smith is pleased to submit these comments as a friend of the Commission.

SECTION III

General Comment

III. GENERAL COMMENT

The Coalition has created an excellent product in drafting modifications to existing FCC rules and in proposing new rules that permit the use of computer modeling using moment method analysis to proof and maintain AM directional antenna arrays. In response to the Public Notice, the comments herein take the liberty to respectfully offer constructive recommendations in an attempt to make the proposed new rules even more effective in guiding the design of AM directional antenna arrays.

As a preface to the recommendations, the Commission is reminded that there has been a diversity in the development of the procedures for applying moment method calculations to broadcast arrays. Engineers of various expertise levels have studied the use of moment method computer programs and each have developed their own post processing software to read data from the standard output file and to use that data to perform the various tasks necessary for broadcast work. (See *Post Processing Yields Improved Parameters for Directional Antennas,* J.L. Smith, PE, 1995 SBE Proceedings, pp49-57). Some engineers have written software to make the moment method programs more user friendly to the broadcaster and some of the more complete efforts have been packaged as commercial products that are offered for sale to the broadcast community. The consensus is, however, that the commercial products all use the same basic moment method engine and they differ mainly in the user interface with, perhaps, some special features added. This is considered advantageous to the task at hand.

Because there has been such a diversity in the development of the procedures for applying moment method calculations to broadcast arrays, there are multiple approaches to accomplish a given analysis and each approach possesses merit of its own. It is prudent, then, that the Commission call for these public comments to obtain the collective knowledge of the broadcast community. It is to that end that these comments are offered.

In their proposed rule §73.151(a)(1)(v), the Coalition permits arbitrary and artificial variation in tower height presumably to facilitate the requirement imposed in §73.151(a)(1) to create a model of the array in which the self impedance of the array elements match measured self impedances. This appears to be an unnecessary requirement and it disrupts a considerable portion of the remainder of the process.

By allowing an artificial tower height, the current distribution on the tower as calculated by the moment method analysis is invalid thus making it unusable for predicting the output of the antenna monitor sampling devices. Presumably, the Coalition has proposed an alternate in §73.151(a)(2)(i) which positions the sampling devices using a procedure that does not rely on the calculated current distribution but instead calls for a detuning process external to the moment method analysis. In so doing, it appears that the Coalition's proposal uses the moment method analysis only to calculate the self impedance of the array elements. This is contrary to what the title of these proceedings imply.

If changing the tower height is prohibited (as it should be) then it is not likely that one can meet the requirement to universally match measured self impedances with calculated self impedances. Thus the requirement for such a match should also be removed. Fortunately, failure to match calculated and measured self impedances causes no harm because the only apparent advantage of such a match is perhaps it serves as an aid in designing the antenna matching network, which is a task external to the issue at hand.

If, on the other hand, the requirement to match self impedances was imposed as an attempt to suggest the integrity of the moment method analysis, then perhaps that attempt is misplaced. A more forthright display of integrity is realized by comparing calculated field ratios and target field ratios as is recommended later in these comments.

These comments offer recommendations that modify the Coalition's proposed §73.151(a) only. The rest of the proposed rules remain as the excellent work they are. Coalition's proposed §73.151(a) is modified by deleting the requirement to match measured and calculated self impedances, by defining the array element model and by using that model in the moment method analysis to completely verify AM directional antenna performance. In addition, a method to verify the integrity of the moment method analysis is also included. All recommended changes support those objectives.

Recommendations and detailed comments thereto are given in Section IV of these comments. Section V presents a revised version of the Coalition's §73.151(a) as modified by these comments.

Section IV

Comments Pertaining To
The Coalition's
Proposed Revisions to Section 73.151

IV. COMMENTS PERTAINING TO THE COALITION'S PROPOSED REVISIONS TO SECTION 73.151

Concerning the Method of Moments Analysis Engine – Coalition's 73.151(a)

Recommendation: It is recommended that any rules adopted by these proceedings apply to the generic use of the NEC2 and NEC4 moment method engines and that the revised rules allow and be consistent with the use of the generic NEC2 and NEC4 output file formats.

Discussion:

Early on, MININEC 3.13 was used for broadcast analysis (See *A Method for Modeling Array Elements When Using NEC and MININEC*, J.L. Smith, IEEE Transactions on Broadcasting, June, 1998) but MININEC had problems analyzing closely spaced wires such as might appear when modeling tower skirts, folded monopoles, guy-wire top loads, etc. NEC2, then NEC4, eliminated those problems and thus are more universal for broadcast applications.

NEC4 is the most advanced program, with additional capability such as allowing the use of buried ground radials, and it will probably be the most supported since it is an active product of Lawrence Livermore National Laboratory (LLNL). It does, however, require a license fee of $1000 or so.

NEC2 is capable of performing quite satisfactorily in broadcast applications and is available free of charge as a public domain program that, although no longer supported by LLNL, it is certainly adequate for this application. Any task mentioned in these comments can be accomplished using NEC2. And when using NEC2, if conditions warrant an upgrade to NEC4, that is certainly feasible since the files created while using NEC2 can be used with NEC4 with only a minor change to the GM command.

Concerning Modeling by Measurement – Coalition's 73.151(a)(1)

Recommendation: It is recommended that the rule requiring that the self impedance of the array elements as modeled match a matrix of measured self impedance values be deleted and replaced with defined models of the array elements.

Discussion:

The revisions to 73.151 as recommended by the Coalition do not define a tower model configuration. Instead it leaves that task to each user individually with the challenge to arbitrarily select tower parameters, including tower height, in an attempt to define a unique set of tower models whose calculated self impedance match a set of measured self impedances. This process is generally referred to as "modeling by measurement".

As written, the unique tower model configuration so determined by the user is required to match the measured impedance values both with the companion towers opened at the base and with the companion towers shorted to ground at the base. This could be a vexing task. This commenter is concerned that should such a rule be implemented it will require an unnecessary effort that is detrimental to the success of the antenna modeling process.

Experience teaches that it is not likely that the required matches could be achieved universally without using an artificial tower height. Fact teaches that the use of an artificial tower height destroys the validity of the moment method analysis thus rendering the effort futile.

The need to match the matrix of impedance measurements as required in the proposed §73.151 (a)(1) is not obvious This commenter has not found that modeling by measurement necessarily contributes an advantage when calculating the radiation pattern.

If the match is used as an aid to designing the antenna matching network, then it is suggested that such can be done "off-line" so to speak. If the match is used as a figure of merit to verify (or signify) the validity of the model, then the model can be verified by comparing the target field ratios and the field ratios determined from ratios of calculated current moments. This is described in detail as a recommendation later under the heading Concerning Confirmation of the Calculated Current Distribution - New 73.151(a)(1)(v).

It is relevant to recognize that there are several ways to influence the calculated self impedance of a radiator; some of which are detrimental rather than beneficial.

Detrimental -

Perhaps the most direct method to influence the calculated self impedance of an array element is to place a shunting reactance across the base insulator using a non-radiating network. This influences the resistive component of the impedance more so than the reactive component so another non-radiating network may be used in series with the source voltage to add needed series reactance. This combination can certainly satisfy the requirement of proposed §73.151 (a)(1) but, unfortunately, it is unusable because this configuration cannot be used when converting field ratios to drive voltages for application in the array. The process of determining the appropriate drive voltages involves individually driving the towers with 1 + j0 volts while the inputs to the companion towers are grounded directly. The use of a series input network does not permit that process thus yielding erroneous drive voltages.

Some engineers have influenced the calculated self impedance of a tower by artificially altering its height. This is not a viable approach because it alters not only the current distribution on the tower but also the radiation pattern and the strength of its radiated field thus destroying the value of those properties for determining pattern size and for positioning the sampling devices. Artificially altering tower height is not recommended by this commenter and is addressed in detail later in these comments.

Beneficial -

A beneficial point concerning model by measurement is that it can be used to create a guide to information leading to the design of the antenna matching network. A reactance shunting the insulator of a radiator, if done realistically, sometimes allows one to set the resistive component of the self impedance to a measured value although it is not likely that the corresponding reactive component will also be in agreement with its measured value. Nevertheless, the reactive component, as obtained, can be used to advantage as a guide to a correction term that may be applied mentally to the reactive component of the calculated operating drive point impedance when designing the antenna matching network.

This is permissible because an added shunt reactance across the insulator of the radiator can be used to affect the calculated self impedance without destroying the validity of the calculated current distribution on the radiator. In an array, the current distribution is determined by the source voltage. The source voltage for broadcast arrays when using a moment method computer program is a voltage source of constant voltage, zero source impedance. Thus, regardless of what impedance the voltage source sees, the voltage is the same therefore the current distribution is the same and the results calculated from that distribution are the same notwithstanding any reactance that might have been placed in parallel with the voltage source. Consequently, a reactance in parallel with the source voltage can be used to modify the calculated impedance without adverse consequence.

But using modeling by measurement to modify self impedance and drive point impedance to design the matching network are internal functions that are not visible when considering the quality of the external radiation pattern and thus they are assumed to be of only passing interest to the Commission in this instance.

Practical Modeling -

Finally, it is significant to mention that there are two reasons why a moment method analysis may not return a calculated self impedance value equal to a measured value.

First off, the model may not include all the real parameters. This is most obvious when calculating the self impedance of a tall tower because tall towers are especially sensitive to the often invisible reactance across the base insulator. Thus it is useful (and often recommended) to add a shunt reactance at the tower base to improve the calculated drive point impedance of tall towers. A measured self impedance can be a useful guide in determining the value of that added reactance.

Secondly, it is commonly known that the moment method analysis may not return a calculated self impedance matching a measured self impedance because of shortcomings internal to the moment method program itself. This is a very important consideration. When parameters such as tower height are varied, the effort may simply rearrange the shortcomings internal to the program so that a 'satisfactory wrong answer' is obtained. In which case, a great deal of harm can be done.

In the end, simple radiator models can create satisfactory results with much less complication. NEC experts have advised that many NEC users overly complicate their models and that best results are obtained with the simple models.

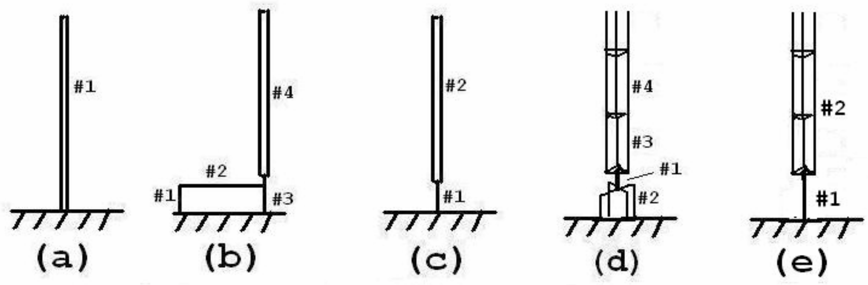
Consequently, these comments recommend that the requirement for the self impedance matching effort be eliminated and recommend that it be replaced with a simple defined tower model with an arbitrary reactance being allowed in parallel with the drive voltage.

<u>Concerning Defined Tower Model Configurations</u> – Coalition's 73.151(a)(1)(i – iv)

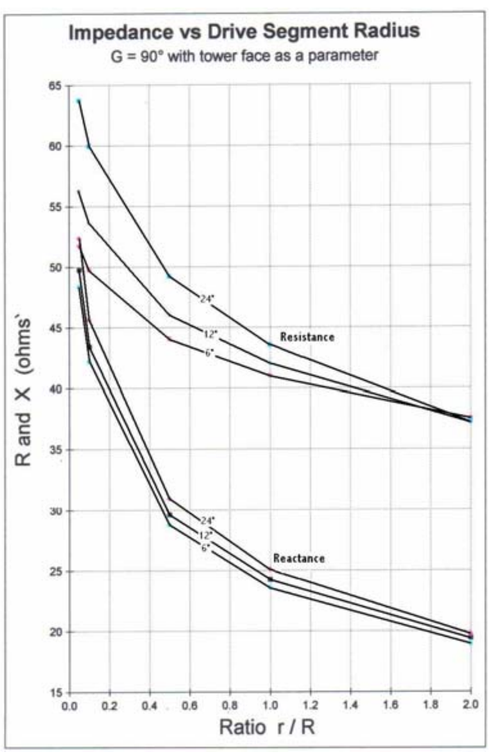
Recommendation: It is recommended that model configurations be defined for both uniform cross section towers and self supporting towers

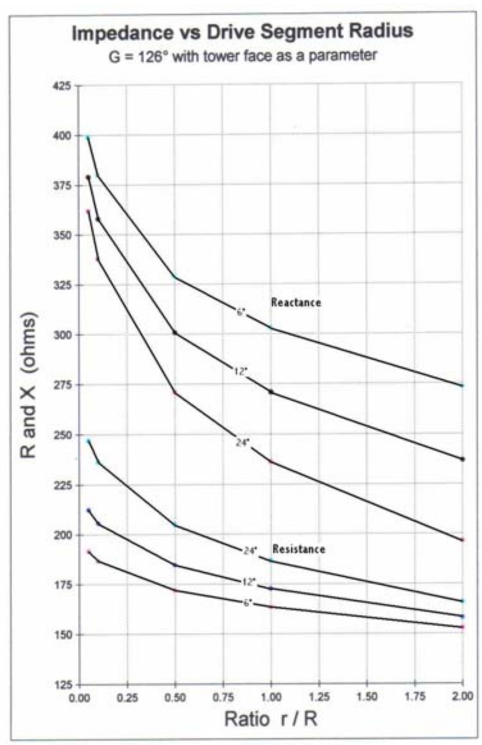
Discussion:

Several tower configuration options are available as shown in the figure. Early on, this commenter used the 4-wire configuration shown in the figure as (b). (See *A Method for Modeling Array Elements When Using NEC and MININEC*, J.L. Smith, IEEE Transactions on Broadcasting, June, 1998) but this configuration has been replaced as the configuration of choice by the 2-wire model shown as (c) when using a thick wire model



and by (e) when using a lattice model. This change in choice was influenced by NEC's difficulty in handling the junction of wires of different radius.





In recognition of the fact that this commenter may not be aware of some compelling reason to have more control over the adjustment of the self impedance of the model, the tower models (c) and (e) as suggested in the recommendation that follows, provide an adjusting capability by varying the radius of the drive segment. This is a practical variable since it, in essence, takes advantage of the character of the NEC2 and NEC4 programs that makes their calculated impedance a function of the parameters of the segment receiving the drive and thus the adjustment does not modify the radiator.

Also, only one arbitrary variable is permitted thus enhancing the likelihood of uniformity among users.

As an interesting aside, the two charts included herein shows the trend of self impedance as the radius of the drive segment is varied.

<u>Concerning Artificially Adjusting Tower Height</u> – Coalition's 73.151(a)(1)(v)

Recommendation: It is recommended that the height of the tower as modeled be defined as fixed at the actual height of the physical tower.

Discussion:

The revisions proposed by the Coalition in 73.151(a)(1)(v) allows the height of the tower to be artificially adjusted in height by as much as +/- 25%. Artificially adjusting the tower height destroys the validity of the moment method analysis because the current distribution calculated for the artificial height differs from that of the actual height.

It is important to recognize that the paramount advantage offered by a moment method analysis is that it can calculate a realistic display of the current distribution on the radiator. Once that current distribution is known, the radiation pattern is known and the antenna monitor indications for the correctly adjusted array can be predicted. In addition, the height at which to place the antenna monitor sampling loops so as to have monitor indications closely approximating the actual radiated field ratios can also be determined. With indications of the radiated field ratios at hand, the networks of the array can be adjusted without relying on field strength measurements made at distant locations.

These comments ask that tower height not be allowed as a variable - in matching calculated self impedance to a measured value or for any other reason. By artificially increasing or decreasing the height of the radiator, the significant benefit of viewing a realistic current distribution on the radiator is lost and the analysis no longer predicts the correct radiation pattern nor is it possible to predict the output of the sampling devices.

Using an artificial tower height is a significant detriment to the basic concept of verifying directional antenna performance by antenna modeling. Unfortunately, no work around remedy for an artificial tower height is apparent. It is not helpful to scale the loop position in proportion to the change in tower height because the optimum loop position does not move in direct proportion as the tower height is changed.

No compelling need to artificially adjust the antenna height is obvious and if allowed, an artificial antenna height destroys the basic foundation of antenna modeling to verify AM directional antenna performance.

<u>Concerning Self Supporting Towers</u> – Coalition's 73.151(a)(1)(vi)

Recommendation: It is recommended that self supporting towers be modeled using a lattice configuration and that they be driven with multiple source voltages.

Discussion:

When the lattice tower configuration is described in the forthcoming recommended changes identified as 73.151(a)(1)(ii) which follow in Section V, the voltage source exciting the tower is placed on a single wire and a spider assembly is used to connect that single feed wire to each of the tower legs. This is a simple model and gives usable results but it has been shown (see Burke & Poggio, "Computer Analysis of the Bottom-fed Fan Antenna" Report No. 173910, Lawrence Livermore National Labs, August, 1976) that a more realistic display of the performance of a lattice tower can be obtained when the drive voltage is made up of several separate and equal voltage sources with one source placed on each of the tower legs. This is equivalent to placing the sources in parallel so the effective voltage remains the same as that of one source but the total current load is shared by the sources. Each voltage source then sees an impedance that is higher than the impedance of the tower, i.e., approximately three times the impedance of the tower for a three leg configuration, four times for a four leg configuration, etc. Also, when the moment method output file displays "Impedance", it will display an impedance for each of the voltage sources. Therefore the tower impedance must be calculated from all the impedances in parallel. However, since the impedances will be very nearly equal, a practical impedance is usually the value of one of the impedances divided by the number of sources.

When the configuration for the self supporting tower is recommended in 73.151(a)(1)(iii) to follow in Section V, this multiple source drive model is included since it is the better way to excite the larger base of the self supporting towers.

<u>Concerning the Location of Sample Loops</u> – Coalition's 73.151(a)(2)(i)

Recommendation: It is recommended that the mounting height of the sample loops be defined as that height where the phase of the tower current goes through the phase of the corresponding field ratio as determined by referring to the current distribution listing generated by the moment method analysis.

Discussion:

The revisions proposed to Section 73.151(a)(2)(i) by the Coalition require that the sample loops be located at the elevation where the current in the tower would be at a minimum if the tower were detuned in the horizontal plane. This requirement is unclear in suggesting that the analysis include a detune process without defining the detuning process. Also, it is supposed that the method may have been recommended because it is recognized that if the tower height is allowed to be changed artificially then the calculated current distribution would be distorted and thus be unusable for positioning the loops. The recommendations in these comments remedy that situation and propose procedures that are carried out totally within the moment method analysis.

While generally used and accepted by most, the word "detune" in itself is a misnomer. In reality the tower is not actually detuned, instead the induced current distribution is adjusted such that the tower current moment is reduced to the point of being insignificant. (see *A Method to Determine the Detuning Reactance for Unused Elements in Directional Arrays*, J.L. Smith, IEEE Transactions on Broadcasting, September, 2001, pp259-262)

The induced current moment can be modified by using various schemes, i.e. by opening the tower base on a short tower, by returning the base to ground through a reactance, by installing tower skirts on tall towers, etc. It is not clear that the proposed requirement could be met in every scheme that might be used to detune a tower. Therefore, a more direct and somewhat more conventional method for positioning the sample loops at the proper height is included in the recommendations of Section V of these comments. The method is based on the moment method analysis as follows.

When the array drive voltages are derived from the field ratios by moment matching, (see *Modeling a Standard Broadcast Directional Array with the Numerical Electromagnetics Code*, C.W. Trueman, IEEE Transactions on Broadcasting, March 1988, pp39-49) the phase of the current moment of a particular tower is the same as the phase of the corresponding far field ratio. Also the phase of the current of a particular tower will go through the phase of the corresponding current moment at the height of the moment center on the tower. Therefore the correct height at which to position the sampling loop is that height where the phase of the tower current goes through the phase of the corresponding field ratio. For example, the correct height at which to position the sample loop on the reference tower of an array is that height at which the current on the reference tower goes through zero degrees. This position can be determined by referring to the current distribution listing generated by the moment method analysis.

Concerning Confirmation of the Calculated Current Distribution - New 73.151(a)(1)(v)

Recommendation: It is recommended that the accuracy of the array model be verified by a favorable comparison of the field ratios as determined from the calculated current moment ratios and the actual target field ratios.

Discussion:

One of the fundamental elements underlying the concept of using antenna modeling to verify AM directional antenna performance is the accuracy of the antenna monitor readings which, of course, depend upon the accuracy of the calculated current distribution on the towers.

Fortunately, the correctness of the calculated current distribution can be verified without difficulty by determining the field ratios generated by the current distributions as calculated and comparing those field ratios to the target field ratios. Consider the following.

The radiated field from tower i is expressed as:

$$E_i = (1/\sqrt{2})\ (j\eta\beta e^{-j\beta r}/2\pi r)\ [\int_0^h I_i(z)dz] \qquad \text{eq(1)}$$

where $I_i(z)$ is the current distribution on tower i and the integral is taken over the height of the tower. The integral within the brackets is the current moment of the tower and its value can be closely approximated by a summation, i.e.

.

$$\int_0^h I_i(z)dz \approx \sum_{j=1}^{N} \Delta_j\, I_j \qquad \text{eq(2)}$$

where N is the number of segments into which the tower was divided for the moment method analysis and Δ_j is the length of segment j as listed in the moment method output file and I_j is the current on segment j as listed in the moment method output file. Noting that the integral, hence the summation, is equal to the current moment then

$$C_i = \sum_{j=1}^{Ni} \Delta_{ij} I_{ij} \qquad \text{eq. (3)}$$

where C_i is the current moment of tower i , N_i is the number of segments on tower i, Δ_{ij} is the length of segment j on tower i and I_{ij} is the current on segment j of tower i. For towers containing wires that are off-vertical such as might be found in top loaded towers, the factor sin α_{ij} may be included within the summation of eq. (3) where α_{ij} is the vertical angle of Δ_{ij} as read from the moment method analysis output file.

Field ratio F_i is the ratio of E_i and E_{ref} where E_{ref} is the field of the reference tower and since the ratio of fields is simply the ratio of current moments then

$$F_i = E_i / E_{ref} = C_i / C_{ref} \qquad \text{eq. (4)}$$

where C_{ref} is the current moment of the reference tower

Thus, the field ratios created by the moment method analysis can be determined by finding the ratio of the calculated current moments of the tower of interest and the reference tower. A simple post processing computer program can be written to read the method of moments analysis output file and do the simple calculations. If correct, the calculated field ratios will compare favorably with the target field ratios.

Comparing the calculated field ratios with the target ratios offers a valid indication of the correctness of the moment method analysis.

Section V

Recommended Changes To
Coalition's Proposed Revisions to Section 73.151

V. RECOMMENDED CHANGES TO COALITION'S PROPOSED REVISIONS TO SECTION 73.151

In keeping with the above commentary, it is recommended that the proposed revisions to Section 73.151 as offered by the AM Directional Antenna Performance Verification Coalition ("Coalition") in their letter dated May 4, 2007 be modified as follows:

Delete::

Delete §73.151 (a) in its entirety starting with

"(a) *Computer modeling and sample system…"*

and ending with

"…shall be placed in the station's public inspection file.".

Add:

Replace the deletion with:

" (a) *Computer modeling and sample system verification to establish the operation of directional antennas in accordance with their theoretical pattern.* Each element of the directional array shall be modeled for use by a method of moments computer program, using the element's physical characteristics to establish a system model that does not violate any of the constraints of the computer program used.

(1) The array shall be modeled using the actual height, spacing and orientation of the array elements. Towers may be modeled in the thick wire configuration using individual vertical wires or in the lattice configuration with multiple wires representing their legs and cross members. The resulting model description (consisting of the length, radius and number of wires to represent the thick wire configuration or the length, end-point coordinates and radius of each wire used to represent legs and cross-members for arrays using the lattice configuration) as well as the assumed base region stray reactance shall be used to generate the sample system parameter values for the operating directional antenna pattern parameters. The height of the modeled tower shall be equal to the height of the actual physical tower measured above ground level.

(i) For arrays using the thick wire configuration to model towers of uniform cross section, the tower model shall be composed of two wires, stacked vertically, with the length of the lower wire being 1/20 of the total tower height. The radius of the lower wire shall be 0.4 times the radius of the upper wire and the lower wire shall be divided into one segment which will be referred to as the drive segment. The source voltage to drive the tower shall be placed on this drive segment. The upper wire shall have a length of 19/20 of the total height with a radius equal to that of a circle whose circumference is equal to the perimeter of the actual physical tower. The upper wire shall be divided into 19 segments.

(ii) For arrays using the lattice tower configuration to model towers of uniform cross section, the tower model shall be composed of two types of sections stacked vertically with the length of each section being 1/20 of the total tower height. The first type of section, type 1, is the lowest section and shall be composed of a single vertical wire divided into 1 segment and extending from ground to 1/20 of the total tower height. That segment will be referred to as the drive segment. The source voltage to drive the tower shall be placed on this drive segment. The type 1 section shall contain a spider assembly at its top end consisting of horizontal wires of sufficient number and length to connect the top end of the single vertical wire to each tower leg. Each horizontal wire of the spider assembly shall be divided into one segment. A horizontal girth ring consisting of horizontal wires of sufficient length and number to connect the far ends of the spider assembly shall be included. Each wire of the girth ring shall be divided into one segment. All remaining sections of the lattice tower configuration are of the second type, type 2, and consist of the appropriate number of vertical section legs positioned as appropriate to imitate the actual physical tower and with a top girth ring as described above connecting the top ends of the section legs. The length of each section leg shall be 1/20 of the total tower height and each section leg shall be divided into one segment. Quantity 19 of the type 2 tower sections shall be stacked vertically on top of a single type 1 section to make the total tower height. The radius of the section legs and spider assembly as modeled shall be equal to the radius of the actual physical tower leg. The radius of the girth ring wires shall be equal to the radius of the horizontal connecting cross members of the actual physical tower. Computer software such as, but not limited to, the GM command in NEC2 and NEC4 may be used to create the lattice tower model.

(iii) Self-supporting towers shall be modeled in the lattice configuration described in (ii) above and shall be composed entirely of type 2 sections unless the actual physical tower carries a pole-like structure in which case the pole-like structure may be modeled as a thick wire. Each section of the self supporting tower shall be dimensioned and tapered from bottom to top as appropriate to imitate the actual physical structure. The bottom end of each of the lowest section legs shall be in contact with ground and each shall be divided into one segment which will be a drive segment. Multiple source voltages shall be employed simultaneously with one source voltage applied to each of the lowest section legs.

(iv) Shunt reactance in parallel with the source voltage may be included to model the base region effects of sample line isolation chokes, isocouplers, etc. using measured values, manufacturer's stated values, or practical and reasonable estimates of those reactances in that order of preference.

(v) The field ratios as calculated from the moment method analysis data shall be verified as correct by a favorable comparison with the corresponding target field ratios. The calculated field ratio shall be determined from the ratio of the calculated current moment of each other tower in the array and the calculated current moment of the reference tower. The current moment for each tower shall be calculated using data from the moment method analysis and the relation

$$C_i = \sum_{j=1}^{Ni} \Delta_{ij}\, I_{ij} \sin \alpha_{ij}$$

where C_i is the current moment of tower i, , N_i is the number of segments on tower i, Δ_{ij} is the length of segment j on tower i, I_{ij} is the current on segment j of tower i and α_{ij} is the vertical angle of Δ_{ij}.

(vi) The orientation and distances among the individual antenna towers in the array shall be confirmed by a post-construction certification by a Land Surveyor (or, where permitted by local regulation, Engineer) licensed or Registered in the State or Territory where the antenna system is located.

(2) Requirements

(i) The array model created in accord with §73.151 (a)(1) shall be used in conjunction with an appropriate method of moments computer program to generate a moment method analysis. The data from the moment method analysis, once verified by a favorable comparison of calculated and target field ratios, shall be used to determine the appropriate antenna monitor parameters. The samples used to drive the antenna monitor may be obtained from current transformers at the output of the antenna matching networks, voltage samples obtained from a voltage sampler electrically connected across the base insulator of the antenna tower, or sample loops located on the tower.

(ii) Sample loops may be employed only when the towers are identical in cross-sectional structure, including both leg and cross member characteristics. If sample loops are used on towers of equal height, they shall be located at the elevation on the tower where the phase of the current in the reference tower goes through zero degrees as determined by an examination of the current distribution listing calculated by the moment method. If the towers are of unequal height, the sample loops shall be mounted on each tower at the elevation where the phase of the current in that tower goes through the phase of the corresponding field ratio as determined by an examination of the current distribution listing calculated by the moment method. The sample loops shall be mounted at the determined height plus or minus a linear distance corresponding to one-half degree (0.5°) of current phase difference as determined by interpolating the current distribution listing at the determined height.

(iii) Sample lines from the sensing element to the antenna monitor must be equal in both length (within plus or minus one electrical degree) and characteristic impedance (within plus or minus two ohms), as established by impedance measurements, including: (A) at the open-circuit resonant frequency closest to carrier frequency to establish length, (B) while open circuited, at frequencies corresponding to odd multiples of 1/8 wavelength immediately above and below the open circuit resonant frequency closest to carrier frequency, to establish characteristic impedance, and (C) at carrier frequency or, if necessary, at nearby frequencies where the magnitude of the measured impedance is no greater than 200 ohms with the sampling devices connected.

(iv) Samples may be obtained from current transformers at the output of the antenna coupling and matching equipment for base-fed towers whose actual electrical height is 120 degrees or less, or greater than 190 electrical degrees. Samples may be obtained from base voltage sampling devices at the output of the antenna coupling and matching equipment for base-fed towers whose actual electrical height is greater than 105 degrees. Samples obtained from sample loops located as described above can be used for any height of tower.

(v) For towers using base current or base voltage sampling derived at the output of the antenna coupling and matching equipment, the sampling devices shall be disconnected and calibrated by measuring their outputs with a common reference signal (a current through them or a voltage across them, as appropriate) and the calibration must agree within the manufacturer's specifications.

(vi) Proper adjustment of an antenna pattern shall be determined by correlation between the measured antenna monitor sample indications and the parameters calculated by the method of moments program, and by correlation between the calculated field ratio for each tower and the corresponding target field ratios.. The antenna monitor sample indications must be initially adjusted to agree with the moment method model within +/- 5 percent ratio and +/- 3 degrees phase. The magnitude of the calculated field ratio must equal that of the target ratio when rounded to two decimal places and be equal in phase when rounded to one decimal place.

(3) Reference field strength measurement locations shall be established in directions where the standard pattern unattenuated field strength is within 3dB of the value for each pattern minimum and for the absolute pattern maximum. The field strength shall be measured at each reference location at the time of the proof of performance and its value, along with a complete description of the location shall be placed in the station's public inspection file."

Section VI & VII

CONCLUSION

VI. NO FURTHER COMMENT

No comment or recommended change is offered to the Coalition's Proposed Revisions to Sections 73.155, 73.61 or the New Rule under Part 17. It is recommended that the Commission accept the proposed revisions to those sections as submitted by the Coalition.

VII. CONCLUSION

The Commission is asked to share the conclusion of this commenter in realizing that it is not necessary that the self impedance of the array elements as calculated by the moment method, match measured values. Given that realization, it is recognized that it is not necessary to permit the tower height to be artificially adjusted. Then when using a true tower height, a valid current distribution can be calculated and verified by field ratio comparison for use in the array verification process.

The primary requirement that is vital to the success of verifying AM directional antenna performance is to accurately know what the antenna monitor will indicate when the array is properly adjusted. To achieve that goal it is first necessary that the monitor give true indications of its input. Secondly it is necessary that the inputs to the monitor be indicative of the array performance. The first necessity is achieved by properly calibrating the monitor system. The second is achieved by providing meaningful samples to the monitor. These meaningful samples are identified from a knowledge of the current distribution on the array elements such as may be obtained from the moment method analysis. Thus the calculated current distribution is the essential result of the moment method analysis in this instance.

The moment method analysis also returns other results that, although not as significant as the current distribution, they are indeed valuable. The calculated drive point impedance of the operating array is very useful in designing the networks even though a moment method analysis may return only a close approximate value. The results are, nevertheless, still beneficial. (See *The Effect of Local Minima on the Adjustment of Complex Directional Arrays,* J.L. Smith, IEEE Transactions on Broadcasting, December, 1998, pp507-516)

There is another less tangible benefit of the moment method analysis that deserves to be mentioned. To borrow a quotation from R.W. Hamming "The purpose of computing is insight, not numbers." A moment method analysis reveals an insight into the operation of the array that would require the distillation of years of experience to obtain otherwise.

In closing, it is a pleasure to take the occasion of these comments to compliment the Commission and the members of the AM Directional Antenna Performance Verification Coalition for their concern in applying their expertise and efforts to this important task. The changes resulting from these proceedings will be the most significant advance in the science since directional antennas came into being in 1935. This commenter is grateful for this opportunity to offer recommendations.

Respectfully submitted,

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/s/ J.L. Smith, PE